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ELECTROLESS NICKEL FILM RESISTORS FOR ELECTRONIC INDUSTRY

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Electroless nickel plating is used increasingly for electronic parts because it can be used for virtually any substrate, whether ceramic, metallic or nonconducting plastic. Resistors used in electronic circuits are normally prepared using carbon or metal films formed by dry processes like sputtering or vacuum deposition on non conducting ceramic substrates. The diameter and length of the substrate varies depending on the resistance and wattage required. The use of such films results in appreciable value of temperature coefficient. In order to reduce the temperature coefficient of such resistors, usually a non metal is incorporated in the film. In the investigations now reported, electroless nickel-phosphorous alloy was coated on the ceramic resistors. Because of codeposition of 3-14% phosphorous in the case of electroless nickel phosphorous alloy plating, the temperature coefficient values of the resistor films thus produced become low. The effects of variation of various parameters of the bath such as composition, *p*H and temperature on the temperature coefficients of Ni-P film resistors are reported in this paper. By suitably adjusting the bath operating conditions, temperature coefficient values of 30 to 60 ppm for nickel-phosphorous alloy coated ceramic resistors could be obtained as required for their use in electronic circuits.

Keywords: Electroless, Ni-P, thin film, resistors and deposition

INTRODUCTION

Electroless nickel plating is used increasingly for the production of electronic parts because virtually any substrate whether ceramic, metallic or non conducting plastic can be plated. Electroless nickel deposits exhibit excellent solderability, conductivity, corrosion protection, receptivity to brazing wire and die bonding and act to retard precious metal migration are an integral part of the fabrication and functional finishing of electronic devices [1-4].

A number of electronic components are plated with electroless nickel to-day. Transistor and diode package bates, caps and pins are plated with electroless nickel to provide corrosion protection and solderability. Electroless nickel-boron alloys are preferred over nickel-phosphorous deposits on capacitors because of its low electrical resistivity and ease of soldering. Transistor chips made from silicon wafers are difficult to solder and often use electroless nickel deposits to form a solderable adherent and ohmic contact on the back side of the wafer which is used as a common ground.

Solar cell production utilizes electroless nickel plating methods. High energy microwave devices including wave guides and circuit often use electroless nickel because it is readily brazed or welded. The principal uses of electroless nickel on printed wiring circuit boards are of wear resistance and diffusion barrier characteristics on plug in contacts and circuit conductors. A deposit of electroless nickel between gold and the copper substrate forms a diffusion barrier that retards the diffusion of copper into gold.

Metallized conductor patterns or uniform metal layers on ceramic substrates have been widely used in the electronics industry. For many years ceramics have been metalized by processes such as the ones using fused metal - glass pastes or by thin film vacuum deposition techniques. Direct electroless deposition with good adhesion of metal to ceramic is now being practiced [5]. Resistors made up of ceramics are coated with metal film for use in electronic circuits. The diameter and length of the substrate varied depending on the resistance and wattage required. The use of carbon or metal film results in appreciable value of temperature coefficient of electrical resistance. In this paper authors have developed an

Presented in the Fifth International Symposium on Advances in Electrochemical Science and Technology, Madras electroless nickel bath which gives low temperature coefficient on ceramic resistors, and studied the effect of bath *p*H and temperature on temperature coefficient of Ni-P film resistors.

EXPERIMENTAL

A number of electroless nickel formulations are reported in literature [6-7].The following bath was selected for the present study.

Nickel sulphate	45 g/l
Trisodium citrate	50 g/l
Sodium Hypophosphate	35 g/l

The ceramic resistors of dia 2mm and length 5mm were first etched in 10% NaOH for 2 to 3 minutes and then sensitized in 10 g/l of stannous chloride and 40 ml/l of hydrochloric acid solution. Then washed thoroughly and activated in 0.5 g/l of $PdCl_2$ and 10 ml/l of HCl solution for 1 to 2 mts and washed. Activated ceramic rods are then coated with electroless nickel at various bath *p*Hs (4.0, 5.0, 6.4, and 8.7). The temperature of the bath was maintained at 353 K using a relay based temperature control unit. The weight of the deposit for each *p*H was determined by stripping the coated samples.

RESISTANCE MEASUREMENT

The variation of resistance of the fabricated resistors with temperature was studied by means of a specially designed apparatus as shown in Fig. 1. It consist of a glass jar with a lid and the lower portion of it is surrounded by a ceramic brick. The jar is heated by means of a heating coil wound

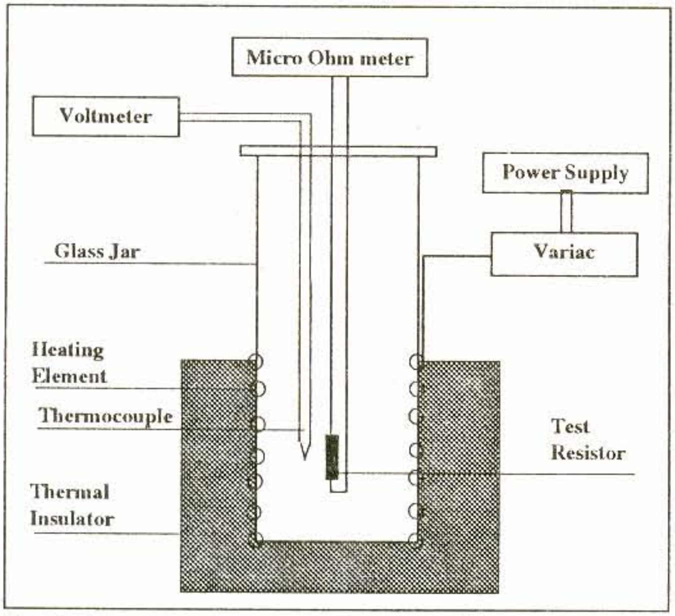

Fig. 1: Apparatus to measure resistance at different temperatures

TABLE I: Resistivity and temperature coefficient of Ni-P sample at different *p*H values

*p*H	Resistivity $\mu\Omega$ cm	Temp coeff. of resistance ppm
4.0	134.50	41.88
5.0	182.60	257.23
6.4	96.34	269.00
7.0	69.34	284.70

over it. The heating coil is connected to supply through variac which is used to vary the current through the coil. The purpose of the ceramic brick is to prevent loss of heat. The sample resistor was hung exactly at the center of the jar from the lid.The leads of the resistor sample was connected to a micro ohm meter with which the resistance was measured. The temperature of the resistor was measured by means of a thermocouple held very close to the resistor so that the calculated temperature was a true measure of the temperature of the resistor. The resistance of the sample was measured between 303 and 373 K. A graph of resistance vs temperature was drawn with temperature on the X-axis. The slope of the graph divided by the intercept value gives the temperature coefficient of resistance.

RESULTS AND DISCUSSIONS

The resistivity values of the resistors fabricated from baths of different *p*Hs is shown in Table I. Table II shows the percentage of phosphorus content with different *p*H values. It is seen from the tables that the phosphorous content plays a major role in the temperature coefficient of resistors. It is reported in the literature [8-10] that inclusion of non metal with electroless nickel coating increases the resistivity of the electroless nickel. In this study during electroless nickel deposition about 6-12% phosphorous is incorporated in the deposit. The inclusion of the phsophorous in the coating depends on the *p*H of the solution. Acid based baths produce higher amount of phosphorous in the electroless nickel coating than alkaline based baths. A good resistor coating should have very low temperature coefficient of resistance. The temperature coefficient of resistance is the ratio of the

TABLE II: Effect of pH on phosphorous content in electroless deposits

*p*H	Percentage of phosphorous
4.0	12
5.0	11
6.4	8
7.0	6

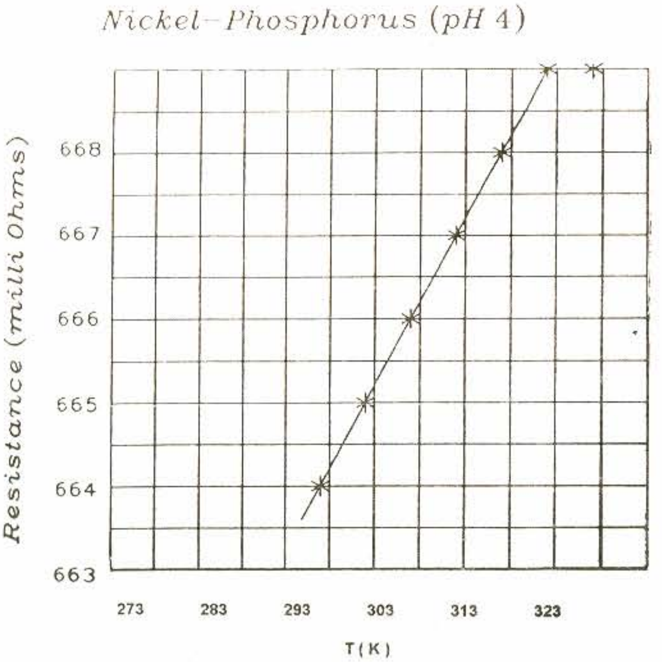

Fig. 2: Effect of temperature on resistance of Ni-P coating produced at pH 4

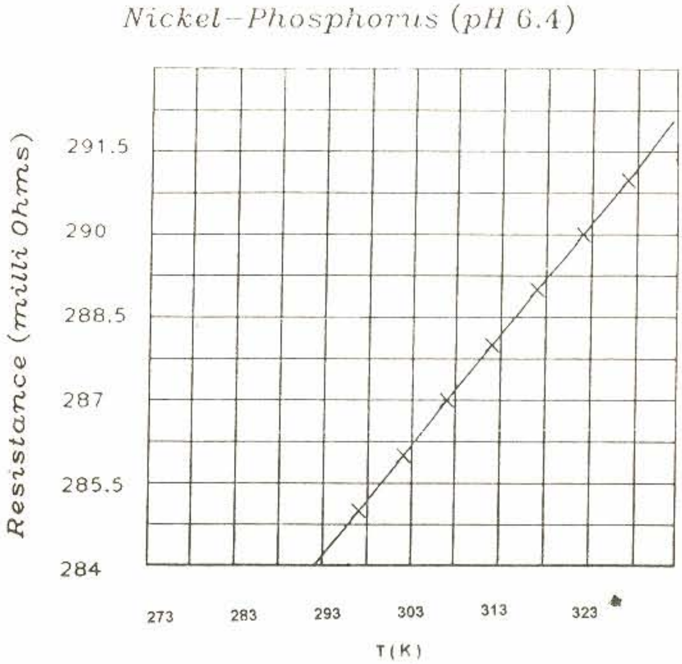

Fig.4: Effect of temperature on resistance of Ni-P coating produced at pH 6.4

increase in resistance of specimen per degree rise of temperature to its resistance at 273 K.

$$R_t = R_0(1 + \alpha t)$$

where R_t = Resistance at t K, R_o = Resistance at 273 K and α = Temperature coefficient of resistance.

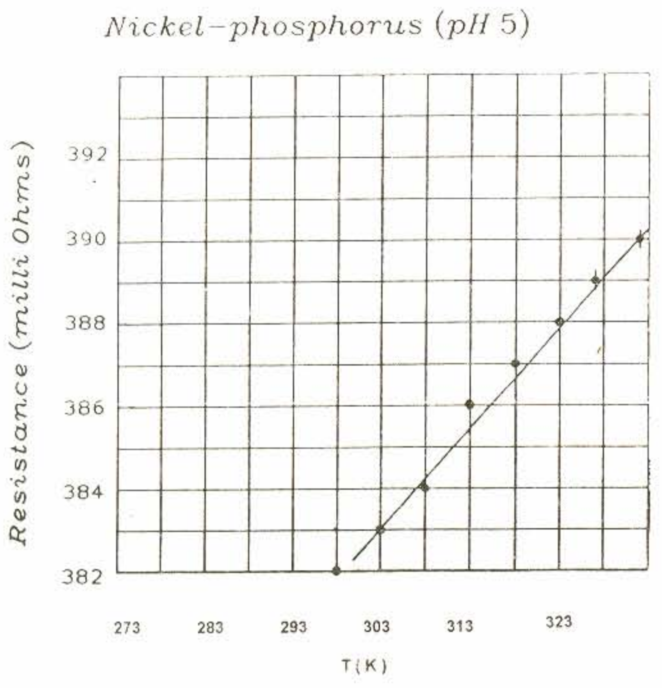

Fig. 3: Effect of temperature on resistance of Ni-P coating produced at pH 5

The variation of resistance of the resistor samples at different temperatures are shown in Figs. 2 to 5 for various *p*H values. Table III shows the effect of temperature on phosphorous content in electroless nickel deposits. It is seen from the table that increase in temperature beyond 353 K reduces the amount of phosphorous in the coating considerably so that

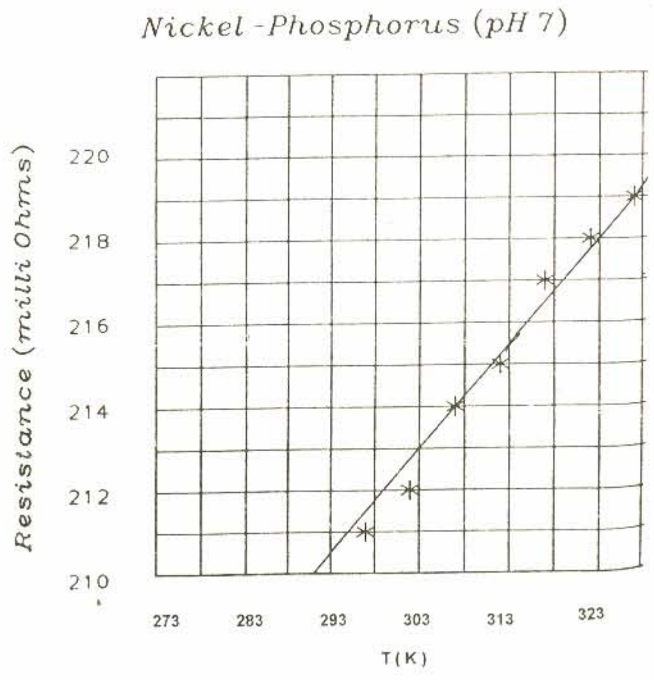

Fig. 5: Effect of temperature on resistance of Ni-P coating produced at pH 7

TABLE III: Effect of temperature on phosphorous content in electroless nickel deposits

Temperature	Percentage of Phorphorous
40	11.2
60	11.0
80	10.9
90	8.0

the temperature of the bath was fixed at 353 K in order to have a high rate of deposition and coverage of the coating on ceramic resistors.

CONCLUSION

Generally nonmetals have negative values of temperature coefficient. Hence proper selection of composition of the metalloid (Ni-P) one can achieve the desired values of temperature coefficient of the metal film resistors used in electronic industries.

It is possible to get electroless nickel phosphorous coating on ceramic resistors with very low temperature coefficient values of 40-60 ppm as required for electronic applications with the following bath formulation and conditions.

Nickel sulphate	45 g/l
Trisodium citrate	50 g/l
Sodium Hypophosphate	35 g/l
*p*H	4
Temperature	353 K

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